

A LATE PALAEOCENE OSTRACODE FAUNA FROM THE PEBBLE POINT FORMATION, SOUTH-WEST VICTORIA

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Forty-four taxa are recorded from the Late Palaeocene Pebble Point Formation, Otway Basin, Victoria. The formation is diachronous. In the absence of diagnostic species, the age assessment of Late Palaeocene must be regarded as tentative. Fresh details are given of *Trachyleberis careyi*, *Margocythere* sp. and a number of previously described *Munseyella* species. Because of the poor preservation of much of the fauna, 23 taxa are left in open nomenclature. Two new species, *Pelecocythere parageois* and *Munseyella kleithria*, are described. The former is the oldest record of this genus and the first occurrence in a shallow-water fauna. The latter species is the most abundant of the substantial population of pelecocytherids and one of the most common elements in the assemblage. The environment was of the marine, inner shelf type and not as high energy as previously thought. The earliest recorded species of *Pelecocythere*, a cosmopolitan deep-water genus in present-day waters, in a relatively shallow-water environment, adds strength to the proposal that many such species originated in shallow waters and have migrated to the deep sea environment subsequently.

Keywords: Ostracoda, Late Palaeocene, taxonomy, palaeobathymetry, Otway Basin, Victoria.

OSTRACODE faunas from the Palaeogene of south-east Australia have recently been described by McKenzie et al. (1991, 1993). Their papers discuss assemblages from the Late Eocene Gull Rock Member of the Blanche Point Formation in the Willunga Embayment of South Australia, the Late Oligocene Jan Juc Formation at Bell's Headland, Victoria and the Middle (?) and Late Eocene Brown's Creek Clay in the Aire River district of Victoria. Majoran (1995, 1996a, 1996b) also discusses Late Eocene ostracodes from the Blanche Point Formation, in South Australia. However, this paper is the first to describe Palaeocene Ostracoda from an Australian locality, and so extends the taxonomic work on south-east Australian faunas across almost the full range of the Tertiary. The Pebble Point Formation is the only fossiliferous marine Palaeocene formation in Victoria and is difficult to access in its coastal outcrops. Extensive picking has produced a substantial assemblage, though many specimens are broken, and adherent matrix makes identification frequently problematical. However, there are sufficient well-preserved specimens free of matrix to permit a reasonably comprehensive description of the fauna.

Evidence of a microfauna in the coeval inland outcrops of the 'Bahgallah Formation' (regarded as a junior synonym of the Pebble Point Formation

[Abele et al. 1988]) has yet to be established. The writer examined core material from two bores in southwestern Victoria which penetrate the Pember Mudstone. Darragh (1994) found bivalves in this material (2125–2131 ft. Kaladbro 2; 1492–1502 ft. Mumbannar 1), though he misidentifies the Mumbannar 1 water bore as the Mersey Valley Oil Co.'s 1926 bore of the same name which bottoms out at 1100 ft. (Spencer-Jones & Kenley 1971). The Pember Mudstone is regarded as a little younger than the Pebble Point Formation (White 1996; Tickell et al. 1992). Kaladbro 2 and Mumbannar 1 (both Department of Mines water bores) yielded a microfauna of *Cyclammina* spp., but no ostracodes.

PREVIOUS WORK

There is no previous published work on the ostracode fauna of the Pebble Point Formation. Neither Wilkinson (1865), nor Murray (1875) makes any reference to a microfauna of this formation. Papers on the molluscs and nautiloids by Singleton (1943) and Tschert (1943) respectively are referred to by Baker (1943), and are the first published formal descriptions of fossils from this formation, apart from brief references in Dennant and Kitson (1903) and Dennant (1904). Parr and Glaessner list foraminifera in an appendix

to Baker's 1943 paper, having had their attention drawn to the microfauna by Baker. They also refer to the occurrence of ostracodes. I have examined material collected by Parr in 1915 for ostracodes, but only two samples, both from Locality PL3003, yielded any specimens. McGowran (1965) refers to the Pebble Point Formation as 'renowned for the rarity and difficulty in extraction of its microfauna'. McGowran (1965, 1970) monographs the foraminiferal faunas of the Pebble Point Formation and the overlying Dilwyn Formation, and deals with their biostratigraphy in detail. Darragh (1985, 1986, 1994) has monographed the bivalves of the molluscan fauna.

LOCATION AND NATURE OF THE FORMATION

The Pebble Point Formation of Baker (1953) is exposed in coastal cliffs. These outcrops are generally sparsely fossiliferous, with the carbonate of the fossils unaltered. Inland outcrops are highly ferruginised and weathered, so that the macrofauna is usually very difficult to determine and often exists only as moulds (Darragh 1994). It is possible that the microfauna of these inland outcrops may have survived the diagenetic changes better than the larger shells, but no work has been done on it at present. Darragh's suggestion that the Palaeocene marine incursion in the Otway Basin may have been far more extensive than previously recognised could be tested by investigating for such a microfauna.

Most of the specimens referred to in this paper come from a cove between 'Buckley Point' and 'Point Pember' (unofficial names given by Baker [1950]), 4.5 km SE of Princetown (GR 894109 Princetown Topographic Map 1:25 000). This is No. PL 3003 in the Museum of Victoria Fossil Locality Register. The specimens occur in 'a dark greenish gray gravelly friable clay' (W. J. Parr's manuscript field notes, held in Museum of Victoria) in a fallen block. A small number of specimens was also recovered from a sample from 'the low cliff midway between Wilkinson's Locality 7 and the next point to the south-east of Point Ronald' (Parr's field notes) PL3001 in the register. This sample was described as 'a gray clay'.

AGE OF THE FORMATION

A tentative assignment of the Pebble Point Formation to the Palaeocene was made by Singleton (1943), although Baker (1953) was still undecided,

and referred to it as 'Lower Eocene to Palaeocene'. Raggatt and Crespin (1955) were virtually convinced that the formation was Palaeocene. A decade later, McGowran's papers (1965, 1970) assign a Middle Palaeocene age, based on planktonic foraminifera. In a later paper (1991), he revises this age upwards to Late Palaeocene, which is accepted by Darragh (1994), although Tickell et al. (1992) state that rare planktonic foraminifera at the type locality indicate mid-Palaeocene Zone P3. The Pebble Point Formation extends in borehole sections into the Late Cretaceous, and so ranges through the whole of the Palaeocene (Tickell et al. 1992), but the outcrops sampled for this study are near the top of the Victorian section. White (1995, 1996) has shown the South Australian section of the Pebble Point Formation in the Gambier Basin ranging from P5 (Late Palaeocene) into P8 (middle Early Eocene), on the basis of pollen zonation and global sequence stratigraphy (McGowran 1991). However, this determination is based on correlating the start of Pebble Point sedimentation with the Pebble Point Ingression (McGowran 1991) in the latest Late Palaeocene. These differences in the age range attributed to the Pebble Point Formation are substantial, with the Cretaceous-Tertiary boundary unconformable in the South Australian sections (White 1995), and conformable in the Victorian sections (Tickell et al. 1992). The formation, as presently defined, is diachronous. In the absence of diagnostic fossils, and in view of the substantial number of taxa in the ostracode assemblage studied here which also occur in Eocene strata (McKenzie et al. 1991, 1993), an age assessment of Late Palaeocene must be regarded as tentative.

COMMENTS ON THE FAUNA

Although initial picking of the samples for this study seemed to indicate that the specimens would be limited both in number and variety, the size and diversity of the assemblage increased markedly as additional material supplied by Dr T. A. Darragh was examined. Over 1000 identifiable specimens were obtained, though many of these are broken or fragmentary.

Preservational characteristics

The preservation of the valves and carapaces is generally good from a broad morphological point of view, though detail at high magnification suffers because of replacement of shell material and/or pitting due to weathering and diagenetic

processes. There is a relatively high proportion of carapaces (14%) in the assemblage, particularly of *Trachyleberis careyi* and *Munseyella* species, indicating rapid burial. Even *Pelecocythere parageois* has an occasional carapace, though the larger specimens of *Trachyleberis* and *Pelecocythere* are often broken or fragmentary. Because of the changes in shell structure referred to above, this breakage may have occurred in the preparation of the samples rather than in the environment of deposition.

Composition

The dominance of the fauna by the large trachyleberid *T. careyi* is quite marked (almost 25%). It is a real dominance, and not due to the large size and robustness of the valves, since substantial numbers of small and relatively fragile specimens have been found in the samples. However, there is a very small proportion of hemicytherids, which is in marked contrast to younger faunas such as that from the Miocene Muddy Creek Marl to the north-west (Neil 1992, 1994). This may reflect the later evolutionary development of hemicytherids in southeastern Australia, since the two most abundant genera in the range of assemblages of Late Oligocene to late Middle Miocene age from right across southern Australia are the hemicytherids *Hermanites* and *Quadracythere* (Neil 1995).

Munseyella species are the second most abundant group (>20%). McKenzie, Reymont & Reymont (1993) have commented on this abundance in relation to the faunas from the Eocene localities of Browns Creek and Castle Cove, which are quite close to Pebble Point. Because of the security of the pentodont hinge, and the lower energy environment, many *Munseyella* specimens are found as carapaces. In general, pelecocytherids do not comprise a substantial component in other southeastern Australian assemblages studied by the writer (Neil 1992, 1994, 1995), although they do form a large proportion of the fauna occurring in the Miocene Upper Morgan and Pata Limestones of South Australia (McHenry, pers. comm. 1996), and the New Zealand Tertiary (Hornibrook 1952; Ayress 1995).

The relative abundance (6th most abundant species) of *Pelecocythere parageios* sp. nov. is a striking feature of the Pebble Point Formation fauna, since the genus has not previously been recorded from a shallow-water environment, nor from other Tertiary faunas from southeastern Australia (see Neil 1992, 1993, 1995; McKenzie 1974; McKenzie et al. 1991, 1993; Warne 1987; Whatley & Downing 1983). It is also the earliest

record of the genus, which is a distinctive element in deep-water faunas in the Pacific and Atlantic Oceans (Benson & Peypouquet 1983; Neale 1988; Whatley & Ayress 1988; Coles, Ayress & Whatley 1990; Whatley & Coles 1991; Correge 1993).

The absence of adult bairdiids, which are also large and robust, is unusual, given the presence of juvenile valves of *Neonesidea* spp. McKenzie et al. (1991, 1993) have not recorded large numbers of bairdiids in their Late Eocene faunas, nor has the common *Neonesidea australis* of the mid-Tertiary been recorded from strata older than the Late Oligocene. However, a complete absence of adult valves is an unusual circumstance. Loxoconchids are absent from the Pebble Point Formation. This contrasts sharply with their abundance in the Middle Miocene Muddy Creek Marl (Neil 1992, 1994) and in the southern Australian assemblages referred to above. The family Nunanidae with new species and genus *Nunana australiae* (McKenzie et al. 1993), is well represented in this assemblage. In diagnosing this new family, McKenzie et al. make reference to some similarities with Xestoleberididae, but the Nunanidae generally stand alone, particularly in relation to their small size.

Rare species, defined as comprising less than 1% of the total, aggregate more than half the number of identified species. This is somewhat surprising, since rare species are often the small fragile ones which have less chance of being preserved. Such small, fragile specimens represent a substantial component of the total assemblage, even allowing for broken and fragmentary material. Some of these rare genera which also occur in deep-water assemblages, and the relative abundance of *Pelecocythere parageois*, point towards a shallow-water origin for what later become diagnostic deep-water forms. This is referred to further in the conclusion to this paper.

The composition of the fauna is thus quite distinctive, even allowing for the occurrence of many species found in the Late Eocene faunas described by McKenzie et al. The dominance of *Trachyleberis careyi* and the notable presence of *Pelecocythere parageios* and ?*Nunana* sp. are positive factors in this distinctiveness, whilst the absence of hemicytherids, loxoconchids and adult bairdiids are negative factors.

CAPTIONS FOR THE PLATES

The specimens are housed in the invertebrate palaeontology collections of the Museum of Victoria, and are identified by numbers prefixed

by the letter P. The following abbreviations are used: RV, right valve; LV, left valve; C, carapace; F, female; M, male; J, juvenile; ext., exterior; int., interior. Locations are indicated in the text. Magnifications are given for each micrograph.

SYSTEMATIC PALAEOLOGY

Note on taxonomic methodology

In dealing with a microfauna which includes many broken and fragmentary specimens, and which exhibits a wide range of preservational effects, it is necessary to make some modification to customary taxonomic procedure. Although a holotype (or type specimen) is designated for each new species which has been erected, the description makes reference to the hypodigm (Simpson 1940) in order to cover a wide range of taxonomic features. Since the fauna includes many broken or poorly preserved specimens with much adherent matrix, it is very difficult to choose a holotype which is sufficiently representative of the full range of taxonomic characters necessary for establishing a new species. On the other hand, choosing additional fragmentary or poorly preserved specimens as paratypes is unsatisfactory, since such specimens often display only one or two important taxonomic characters in an otherwise unrepresentative context. Measurements of the holotype are given in millimetres, together with the range of dimensions shown by the hypodigm, where appropriate. The classification followed is generally that put forward by Hartmann & Puri (1974).

A complete species/location list is available from the author.

Order PODOCOPIDA G. W. Mueller, 1894

Suborder PLATYCOPA Sars, 1866

Family CYTHERELLIDAE Sars, 1866

Cytherella Jones, 1849

Type species. *Cytherina ovata* Roemer 1840.

Cytherella cf. *pinnata*

McKenzie, Reymont & Reymont, 1993

Cytherella pinnata McKenzie, Reymont & Reymont 1993: 78, pl. 1, figs 1, 2.

Figured specimens. Fig. 4C (P146936); Fig. 9F (P146974).

Remarks. This species of *Cytherella* is very close in shape to *C. pinnata*, but it is smaller than that species. It constitutes a substantial proportion of the assemblage (7.9%). Since the muscle scars cannot be distinguished, though some specimens are well-preserved, these specimens can only be compared with *C. pinnata*. A relationship from the Late Palaeocene of Pebble Point to the nearby Late Eocene of Brown's Creek and Castle Cove is quite possible.

Measurements. P146936—L=0.56, H=0.36; P146974—L=0.78, H=0.50.

Material studied. 83 specimens, some broken, and including males, females, carapaces and juveniles.

Occurrence and age. 79 from PL3003; 1 from between Buckley's Point and Point Margaret; 3 from SE of Point Pember, PL3001 (W. J. Parr Collection). Late Palaeocene.

Cytherelloidea Alexander, 1929

Type species. *Cythere (Cytherella) williamsoniana* Jones 1849.

Cytherelloidea marginopytta

McKenzie, Reymont & Reymont, 1991

Cytherelloidea sp. McKenzie 1979: 90, p. 11, fig. 7.

Cytherelloidea marginopytta McKenzie, Reymont & Reymont 1991: 140, pl. 2, fig. 1; pl. 10, figs 2, 3.

Cytherelloidea marginopytta McKenzie, Reymont & Reymont 1993: 79, pl. 1, fig. 10.

Figured specimen. Figs 4A, B (P146935).

Remarks. McKenzie et al. (1993) allow a range of ornament in this species. The single specimen figured here is somewhat smaller, has a more marked marginal ridge and a slightly different pattern of pitting from those previously described, but is regarded as conspecific with them because of its basic pattern of ornamentation. Specimens of *C. marginopytta* occur in the collections of the writer from Fishing Point (Early Miocene); Point Addis (Late Oligocene) and Clifton Bank (late Early Miocene).

Measurements. P146935—L=0.59, H=0.36.

Material studied. 1 valve, possibly a juvenile.

Occurrence and age. PL3003. Late Palaeocene. *Cytherelloidea* sp. McKenzie 1979 from the Late Eocene Gull Rock Member, Blanche Point Formation of the Willunga Embayment, South Australia; specimens from the Late Oligocene at Bell's Headland and Point Addis and Miocene specimens referred to above give a range from Late Palaeocene to late Early Miocene.

Suborder PODOCOPA Sars, 1866

Family BAIRDIIDAE Sars, 1888

Neonesidea Maddocks, 1969

Neonesidea spp.

Figured specimen. Fig. 4G (P146940).

Remarks. A small number (8 specimens) of juvenile *Neonesidea* spp., mostly fragments, were recorded. A well-preserved specimen has been figured.

Measurements. P146940—L=0.53, H=0.30, W=0.12.

Material studied. 8 specimens.

Occurrence and age. PL3001; PL3003. Late Palaeocene.

Family CYTHERIDAE Baird, 1850

Subfamily CYTHERINAE Baird, 1850

Microcytherura Mueller, 1894

Type species. *Microcytherura nigrescens* Mueller, 1894

Microcytherura sp.

Figured specimens. Fig. 6A; Fig. 10D (P146950, P146979).

Remarks. The presence of several species from the *Loxocythere/Microcytherura* continuum (see Hartmann 1982) is a distinctive feature of this assemblage. These specimens have a closely punctate surface with some evidence of reticulation (Fig. 10D), reminiscent of the Recent form *M. peterroyi* Yassini and Jones 1995.

Measurements. P146950—L=0.36, H=0.20, W=0.12; P146979—L=0.34, H=0.19, W=0.12.

Material studied. 7 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Loxocythere Hornibrook, 1952

Type species. *Loxocythere crassa* Hornibrook, 1952.

Loxocythere malzi

McKenzie, Reymont & Reymont, 1993

Loxocythere malzi McKenzie, Reymont & Reymont 1993: 84–86, pl. 2, fig. 5.

Figured specimens. Fig. 6D (P146953); Fig. 81 (P146971).

Remarks. This species is a relatively common component in the assemblages. Although McKenzie et al. (1993) illustrate only one specimen, a broken female carapace, from a total of 12 specimens, their description makes it clear that these Pebble Point specimens are conspecific.

Measurements. P146953—L=?, H=0.28; P146971—L=0.46, H=0.30, W=0.11.

Material studied. 37 specimens, many broken or fragmentary.

Occurrence and age. PL3003. Late Palaeocene.

Loxocythere sp. aff. *L. hornibrooki*
McKenzie, 1967

Loxocythere hornibrooki McKenzie 1967: 68–69, pl. 11, fig. 2.

Loxocytherura (*Loxocythere*) *hornibrooki* Hartmann 1982: 120–121, text-figs 1, 2, pl. 1, figs 1, 2.

Figured specimens. Figs 6E, G (P146954, P146956).

Remarks. Although these specimens are Palaeocene, and McKenzie's and Hartmann's are from the Recent, there is a substantial similarity in the reticulation. Internal features cannot be compared because of poor preservation and adherent matrix, but McKenzie's (1967) comment '... reticulate carapace in which the reticules themselves are microreticulate or micropunctate' is borne out with these specimens. Sexual dimorphism noted—males longer and less high.

Measurements. P146954—L=?, H=0.26; P146956—L=0.51, H=0.25.

Material studied. 2 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Loxocythere sp. cf. *L. ouyenensis*
(Chapman, 1914)

Cytherura ouyenensis Chapman 1914: 44–45, pl. 8, figs 35a, 35b.

Loxocythere ouyenensis McKenzie 1981: 106.

Figured specimen. Fig. 6C (P1469952).

Remarks. This specimen is more strongly reticulated than Chapman's species, which shows signs of abrasion that may have reduced the ornamentation. I have found specimens in the Miocene Muddy Creek Marl which are less markedly reticulate but in other respects very similar to the Pebble Point material. There is no evidence of microreticulation or micropunctuation as in the material from this assemblage assigned to *L.* sp. aff. *hornibrooki*.

Measurements. P146952—L=0.49, H=0.26, W=0.15.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Family PECTOCYTHERIDAE Hanai, 1957

Remarks. Genera of this family are well represented in the assemblages described by McKenzie, Reymont & Reymont (1993) from the Eocene Browns Creek Clays of Brown's Creek and Castle Cove close to Pebble Point. The family is largely unrepresented in the assemblages from the Eocene of South Australia (no specimens) and the Oligocene of the Victorian coast further east from Pebble Point (three specimens), which these writers have also monographed, although Majoran (1995, 1996) records pectocytherids from the Eocene of the Port Willunga Embayment. The abundance of pectocytherids in the Cape Otway section of the Victorian coastal Tertiary deposits is therefore a distinctive provincial feature.

Premunseyella Bate, 1972

Type species. *Premunseyella ornata* Bate, 1972.

?*Premunseyella imperfecta* Bate, 1972

Figured specimen. Fig. 2F (P146926).

Remarks. A single valve, similar to those figured by Bate (1972) and Neale (1975), though exterior preservation is not as good.

Measurements. P146926—L=0.46, H=0.20.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Munseyella van den Bold, 1957

Type species. *Munseyella hyalokystis* (Munsey, 1953).

Munseyella kleithria sp. nov.

Etymology. From the Greek *kleithria*—a keyhole; a reference to the characteristic pierced area of the reticulation.

Types. Holotype—P146910 (LV); Paratypes—P146911 (carapace), P146912 (RV), P146913 (LV), P146914 (RV).

Figured specimens. Figs 2A, B, C (P146910, P146911, P146912); Figs 9D, E (P146913, P146914).

Type locality. PL3003. Late Palaeocene.

Diagnosis. A strongly reticulate *Munseyella*, with a pierced fossa subcentrally, and a marked, narrow marginal ridge on all sides.

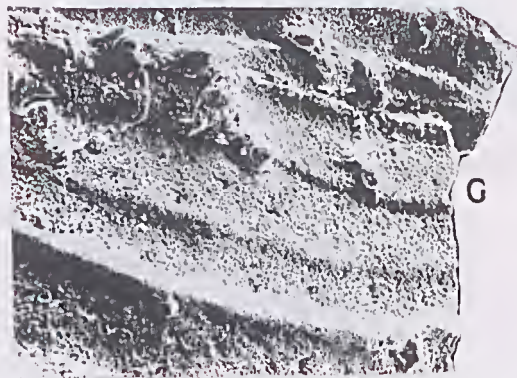
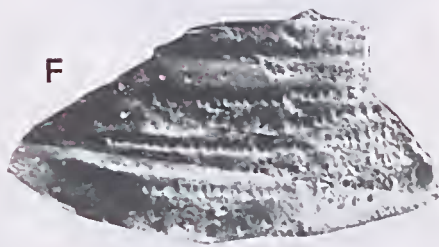
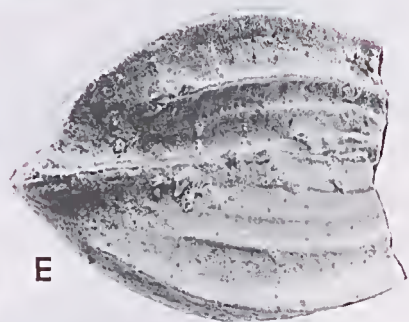
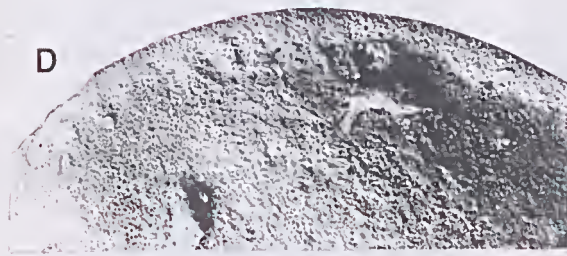
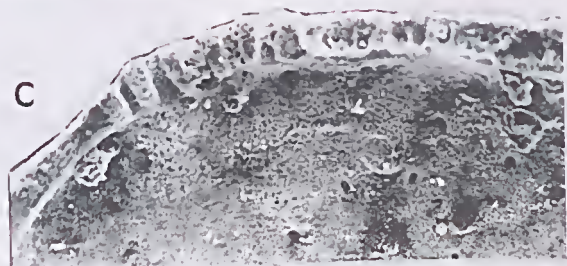
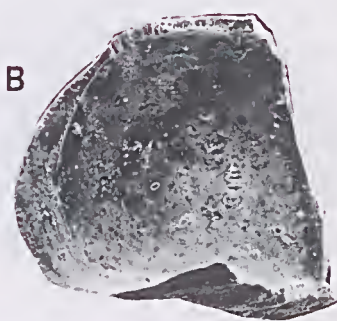
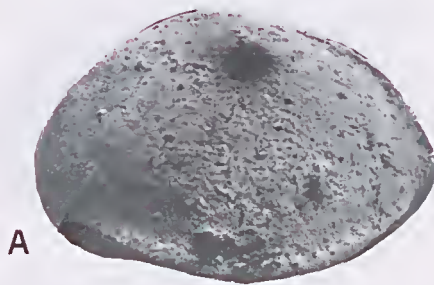
Description. Valves subquadrate, with females higher anteriorly than males. Reticulation strongly developed; sharp-edged muri; pierced fossa just below subcentral area; lateral lines of reticulation meander from anterior to posterior, with vertical borders of fossae not linked. Marginal flange almost complete from posterodorsal indentation clockwise through venter, anterior and dorsum, terminating with inclined ridge from posterodorsal angle to a postero-medial point behind posterior flange. Postero-dorsal angle marked by high, sharp, concavity of flange. Flange sharp-edged and concave inwards. Anterior groove behind flange. No eye tubercle.

Internal features not readily discerned. Inner lamella narrow in both anterior and posterior. No vestibules. Muscle scars not determined. Hinge pentodont, median bar probably crenulate.

Affinities. *M. kleithria* is the most strongly reticulate species of this genus from southeastern Australia. Most of those figured by McKenzie et al. (1991, 1993) are either punctate, punctate-reticulate or have large, rounded ridges. These latter species are represented in this assemblage (see below). *M. splendida* Whatley & Downing (1983) is also characterised by large, rounded ridges. *M. sp.* McKenzie (1974) is reticulate, but in broader style, as well as having two caudal projections, and in the author's view is better assigned to *Keijia*. McKenzie (1979) figured a punctate *Munseyella* from South Australia. *M. modesta* Swanson and *M. pseudobrevis* Ayress from the Eocene of New Zealand, and *Swansonites intermedia* Milhau, which is also a *Munseyella*, from the Miocene of New Zealand, are likewise not strongly reticulate. *M. punctata* Yassini & Jones, from the Recent of Bass Strait, is a punctate form.

I found no reticulate *Munseyella* species in the Middle Miocene Muddy Creek Marl of south-western Victoria (Neil 1992).

Fig. 1. All figures are of *Pelecocythere parageois* sp. nov. A, P146905 LV ext. $\times 45$. B, P146906 RV int. $\times 60$. C, P146906 RV anterior hinge elements $\times 180$. D, P146905 LV detail of alar flange $\times 90$. E, P146907 C ventral surface (broken specimen) $\times 60$. F, P146908 J ventral surface detail (broken specimen) $\times 90$. G, P146907 C ventral surface detail $\times 135$.



Remarks. The abundance of this species of *Munseyella* (and of other species of the genus) in this assemblage is noteworthy, and is congruent with the large numbers of specimens of the genus found in Victorian Eocene localities by McKenzie et al. (1993). Generally, pectocytherids are representative of shallow-water environments (McKenzie 1979).

Measurements. P146910 (Holotype)—L=0.52, H=0.28; P146911 (Paratype)—L=0.52, H=0.24, W=0.24; P146912 (Paratype)—L=0.51, H=0.28; P146913 (Paratype)—L=0.48, H=0.24; P146914 (Paratype)—L=0.51, H=0.25.

Hypodigm ranges (adults). Length 0.50–0.52, height 0.24–0.28, width 0.11–0.12.

Material studied. 102 specimens, including 44 carapaces and some identifiable fragments.

Munseyella warringa

McKenzie, Reymont & Reymont, 1993

Munseyella warringa McKenzie, Reymont & Reymont, 1993: 96, pl. 4, figs 11–13; pl. 8, fig. 9.

Figured specimens. Fig. 2E; Fig. 10F (P146918).

Remarks. These specimens conform to the somewhat variable criteria set down by McKenzie et al. (1993). Polymorphism of the punctation is reflected in the absence of ridging between the punctae (as in fig. 13 of pl. 4). The medioventral ala is not marked, but the characteristic knob is evident.

Measurements. P146918—L=0.38, H=0.19.

Material studied. 16 specimens.

Occurrence and age. PL3001; PL3003. Late Palaeocene.

Munseyella dunoona

McKenzie, Reymont & Reymont, 1993

Munseyella dunoona McKenzie, Reymont & Reymont 1993: 96, pl. 4, figs 7–10.

Munseyella dunoona Majoran 1995: 77, fig. 3L.

Munseyella dunoona Ayress 1995: 909, fig. 8, nos 10, 11.

Figured specimens. Figs 2H, I (P146920, P146921).

Remarks. *M. dunoona* occurs in limited numbers in these assemblages. These specimens show the almost complete marginal ridge and branching 'crossroad' pattern referred to by McKenzie et al. (1993) making them conspecific. The specimen figured by Majoran (1995) does not clearly show these features.

Measurements. P146920—L=0.47, H=0.23, W=0.20; P146921—L=?, H=0.22.

Material studied. 12 specimens.

Occurrence and age. PL3001, PL3003. Late Palaeocene.

Munseyella sp. cf. *M. adaluma*

McKenzie, Reymont & Reymont, 1993

Munseyella adaluma McKenzie, Reymont & Reymont 1993: 94, 96, pl. 4, figs 3–6; pl. 8, fig. 8.

Figured specimens. Fig. 2D; Figs 8B, D; Fig. 10B (P146915, P146922, P146924).

Remarks. It is sometimes difficult to discern the pattern of ornament in the reticulate and punctate forms of *Munseyella* in this assemblage, because of the effects of weathering and diagenesis (Fig. 10B). These specimens are closest to *M. adaluma* with their deeply punctate lateral surfaces, and strongly developed anterior ridge with two deep arcuate loculi behind it. However, the absence of a postrodorsal projection and the random distribution of punctae make their assignment to *M. adaluma* tentative.

Measurements. P146915—L=0.48, H=0.23, W=0.18; P146922—L=0.41, H=0.21; P146923—L=0.46, H=0.21, W=0.18.

Material studied. 5 specimens.

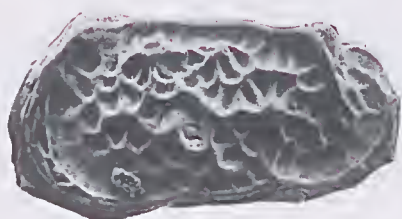
Occurrence and age. PL3003. Late Palaeocene.

Munseyella sp. cf. *M. bungoona*

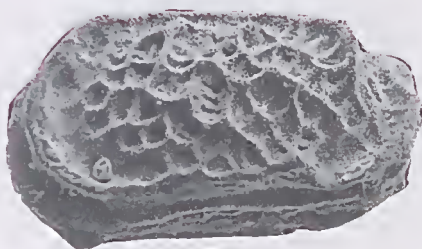
McKenzie, Reymont & Reymont, 1993

Figured specimens. Figs 2G, J; Fig. 9C (P146916, P146917, P146919).

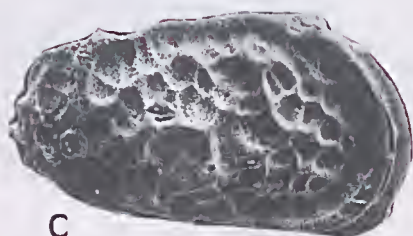
Fig. 2. A, *Munseyella kleithria* sp. nov. P146910 LV ext. $\times 100$. B, *Munseyella kleithria* sp. nov. P146911 C (LV) ext. $\times 100$. C, *Munseyella kleithria* sp. nov. P146912 RV ext. $\times 110$. D, *Munseyella* sp. cf. *M. adaluma* P146915 C (LV) $\times 120$. E, *Munseyella warringa* P146918 RV ext. $\times 150$. F, ?*Premunseyella imperfecta* sp. P146926 F, RV ext. $\times 140$. G, *Munseyella* sp. cf. *M. bungoona* P146916 C (LV) $\times 140$. H, *Munseyella dunoona* P146920 RV ext. $\times 120$. I, *Munseyella dunoona* P146921 LV ext. (broken specimen) $\times 120$. J, *Munseyella* sp. cf. *M. bungoona* P146917 LV ext. $\times 150$.



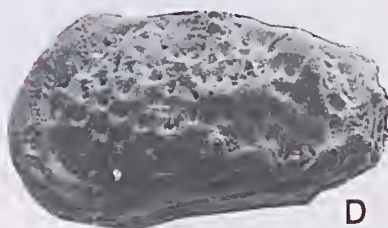
A



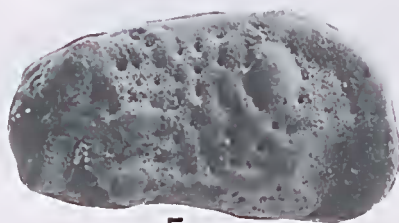
B



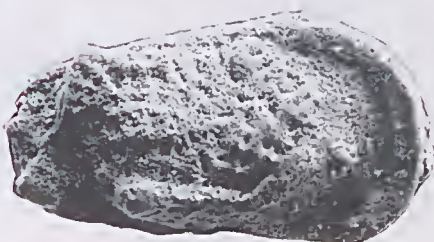
C



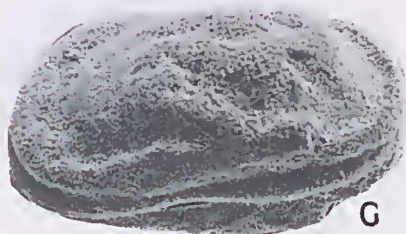
D



E



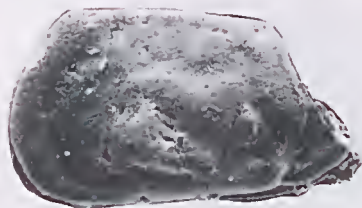
F



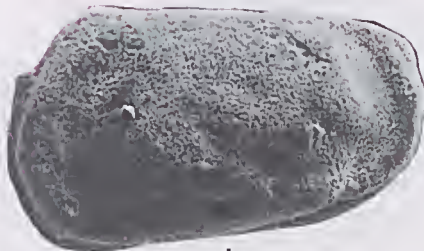
G



H



I



J

Remarks. These specimens form a significant part of the assemblage, being the seventh most abundant species. The relatively smooth surface makes comparison with *M. bungoona* somewhat difficult, especially since most specimens are preserved as carapaces, and the valves are not easily separable without breakage. The few separate valves do not show internal features clearly. Furthermore McKenzie et al.'s figures are somewhat indistinct and the 'poorly expressed median ridge' can scarcely be regarded as a diagnostic feature. The greatest similarity is with the 'relatively plump' shape, and the rounded, subquadrate lateral aspect. Only tentative referral to *M. bungoona* is possible.

Measurements. P146916—L=0.44, H=0.19, W=0.19; P146917—L=0.43, H=0.23; P146919—L=0.42, H=0.23.

Material studied. 64 specimens.

Occurrence and age. PL3001; PL3003. Late Palaeocene.

?*Munseyella* sp. indet.

Figured specimen. Fig. 8E (P146925).

Remarks. This single specimen is tentatively assigned to *Munseyella* on the basis of size, shape and marginal ridging, which is similar to that of *Munseyella kleithria* sp. nov. However, the pentodont hinge is not clearly preserved, and the lateral surface suggests some taphonomic deformation.

Measurements. P146925—L=0.41, H=0.20.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Subfamily LEPTOCYOTHERINAE Hanai, 1957

Callistocythere Ruggieri, 1953

Type species. *Callistocythere littoralis* (Mueller, 1894).

?*Callistocythere* sp.

Figured specimen. Fig. 6F (P146955).

Remarks. This single large specimen has well-preserved external features, but lacks detail internally. Valve shape is gently rounded anteriorly, with a straight venter, and an arched dorsal margin with greatest height forward of the mid-point. There is a narrow marginal ridge, marked in the posterior, but less so in the anterior. The ridged pattern is basically longitudinal, with a strong anterodorsal ridge paralleling the margin. The subcentral area is marked by a small fossa. There is a narrow trough forward of the posterior ridge. RV does not show diagnostic hinge features for *Callistocythere*. Muscle scars not detected. The specimen is tentatively assigned to *Callistocythere*, because of its general shape and ornamentation.

McKenzie, Reymont & Reymont (1993) figure a single valve which does not have the marked ridge pattern of this specimen. They comment on this Late Eocene occurrence being the earliest record for the genus in Australia. This range may well be extended to the Palaeocene if further material of ?*Callistocythere* sp. is found.

Leptocytherid gen. and sp. indet.

Figured specimen. Fig. 8C (P146923).

Remarks. One specimen, which has the characteristic leptocytherid shape, but is unlike ?*Callistocythere* sp.

Measurements. P146923—L=0.37, H=0.21.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Family EUCYOTHERIDAE Puri, 1954

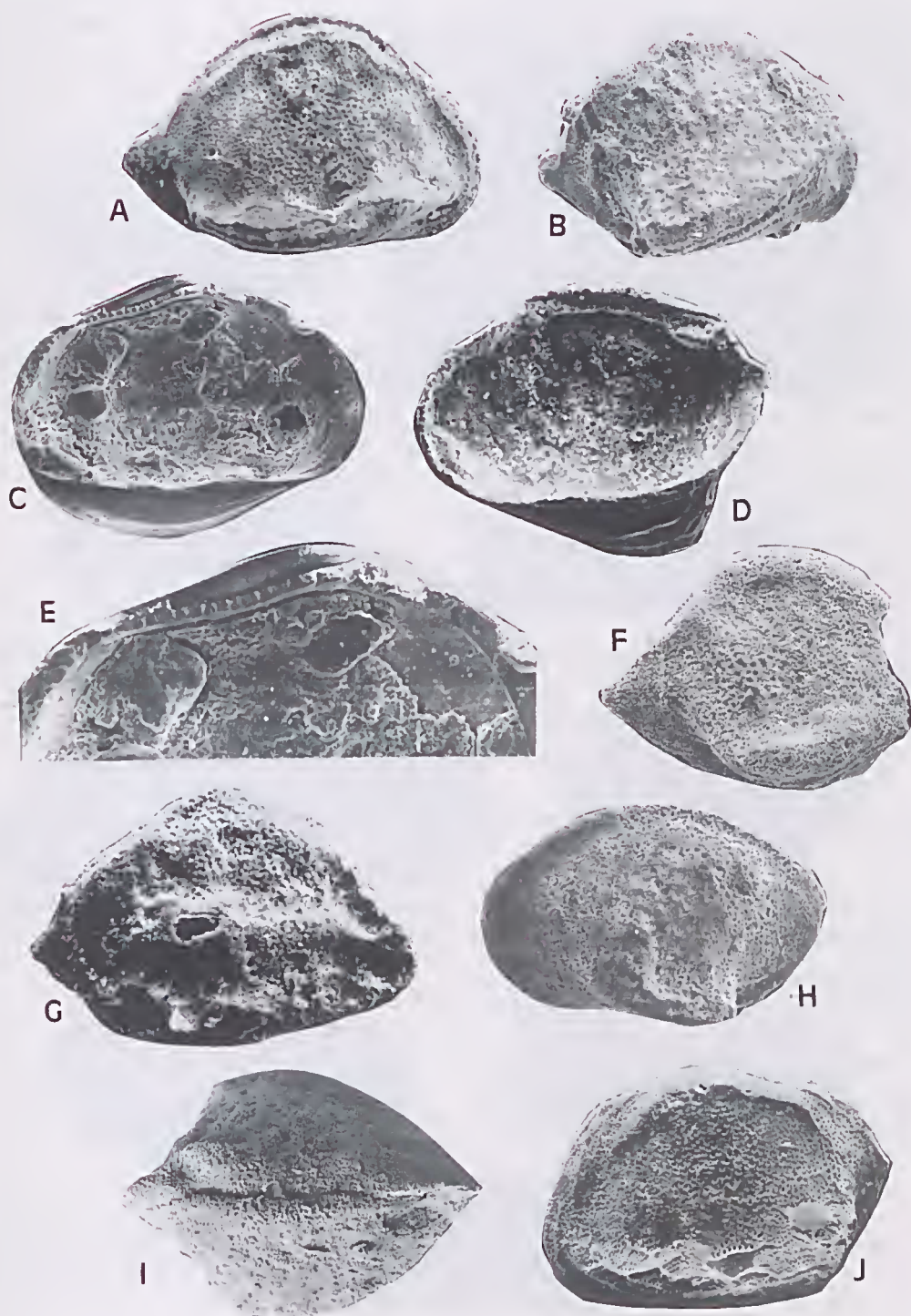
Eucythere Brady, 1868

Type species. *Eucythere declivis* (Norman, 1865).

Eucythere sp. 1

Figured specimen. Fig. 6H (P146957).

Fig. 3. A, ?*Oculocytheropteron australopunctatarum* P146927 RV ext. $\times 100$. B, ?*Oculocytheropteron* sp. 2 P146928 RV ext. $\times 125$. C, *Pelecocythere parageois* sp. nov. P146909 RV int. $\times 55$. D, ?*Oculocytheropteron* sp. 2 P146929 RV int. $\times 120$. E, *Pelecocythere parageois* sp. nov. P146909 RV detail of hinge line $\times 100$. F, ?*Oculocytheropteron* sp. 1 P146930 RV ext. (broken specimen) $\times 140$. G, *Kangarina* sp. P146931 RV ext. $\times 175$. H, *Aversoalva* sp. P146932 LV ext. $\times 140$. I, *Aversoalva* sp. P146933 C dorsal view $\times 120$. J, ?*Oculocytheropteron australopunctatarum* P146934 LV ext. (slightly crushed) $\times 130$.



Remarks. This species is a common component of the assemblage from PL3003. The specimens are thin-shelled and show a lightly ribbed surface marked by deep punctae, and a compressed caudal extension. Other assemblages from south-eastern Australia have *Pseudeucythere* and *Rotundracythere*, both of which genera have a more acute dorsal angulation than *Eucythere*.

Measurements. P146957—L=0.29, H=0.18.

Material studied. 38 specimens, mostly fragmentary.

Occurrence and age. PL3003. Late Palaeocene.

Eucythere sp. 2

Figured specimens. Figs 8G, 1; Fig. 10C (P146969, P146971).

Remarks. Although better preserved than *Eucythere* sp. 1, there are too few specimens to justify the erection of a new species. The specimens show a finely punctate surface (Fig. 10C), with some shallow depressions medially. There is no compressed caudal extension, and the posterior is more broadly rounded than in the generally smaller specimens of *Eucythere* sp. 1.

Measurements. P146969—L=0.36, H=0.20; P146971—L=0.46, H=0.30, W=0.11.

Material studied. 7 specimens (5 from PL3001 and 2 from PL3003).

Occurrence and age. PL3001; PL3003. Late Palaeocene.

Rotundracythere Mandelstam, 1960

Type species. *Rotundracythere rotunda* (Hornibrook, 1952).

Rotundracythere rotunda (Hornibrook, 1952)

Eucythere rotunda Hornibrook, 1952: 30, pl. 2, figs 22, 23, 25.

Rotundracythere cf. *rotunda* Hornibrook, 1952.—McKenzie, Reymont & Reymont, 1993: 88–89, pl. 3, fig. 3.

Figured specimen. Fig. 6I (P146958).

Remarks. These specimens are similar to that figured by McKenzie et al. (1993), but show a

more distinct pattern of reticulation and punctuation. The crenulate median hinge element places them in *Rotundracythere* rather than *Eucythere*, but the dorsum has a less marked angulation than that which characterises specimens figured by Hornibrook (1952), Swanson (1969, 1980) and Warne (1987). The male specimens are more elongate than is usual in *Rotundracythere*. One female specimen is more characteristically of *Rotundracythere* shape, but the reticulation and punctuation clearly shown on the male specimens is not well-preserved here, though there is some suggestion of a slight anterior flange.

Hornibrook's original figures (1952) seem to show a distinct anterior flange, though this is not mentioned in the description. All subsequent figures by the later authors referred to here show flangeless valves. The surface reticulation, punctuation and the median sulcus establish their conspecificity with the Hornibrook species and extend its range to the Late Palaeocene.

Measurements. P146958—L=0.36, H=0.21.

Material studied. 13 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Family NEOCYTHERIDEIDAE Puri, 1957

Copytus Skogsberg, 1939

Type species. *Copytus caligula* Skogsberg, 1939.

Copytus sp. cf. *C. rara* McKenzie, 1967

Remarks. These four specimens are infilled with matrix, so internal features cannot be determined. Their smooth shells and characteristic shape suggest McKenzie's 1967 Recent species from Port Phillip Bay.

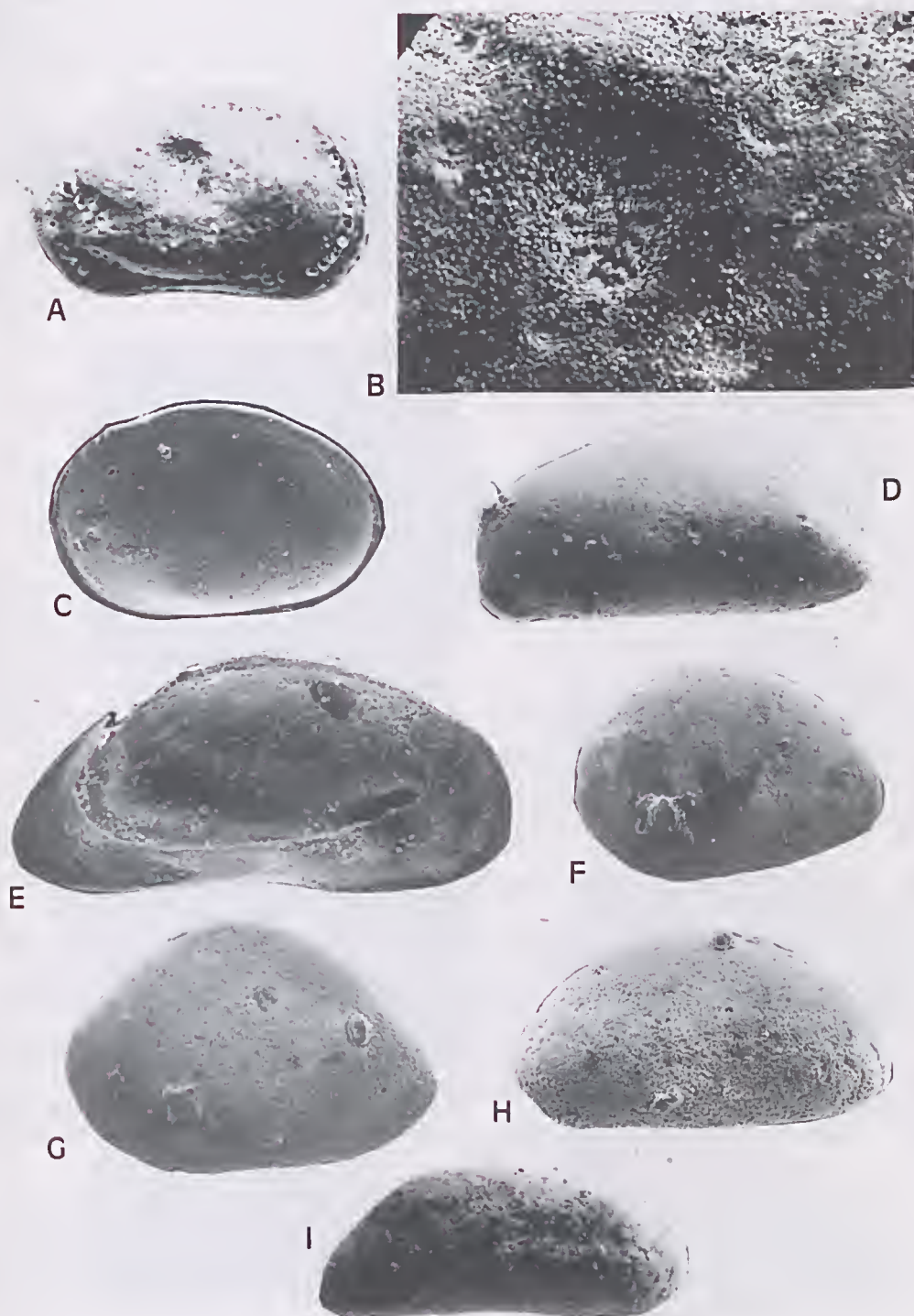
Material studied. 4 specimens, two broken.

Occurrence and age. PL3003. Late Palaeocene.

Neocytherideis Puri, 1952

Type species. *Neocytherideis elongata* Puri, 1952.

Fig. 4. A, *Cytherelloidea marginopytta* P146935 RV ext. $\times 80$. B, *Cytherelloidea marginopytta* P146935 detail of muscle scars (ext.) $\times 350$. C, *Cytherella pinnata* P146936 RV int. $\times 95$. D, *Tasmanocypris* sp. P146937 LV ext. $\times 80$. E, *Tasmanocypris* sp. P146938 LV int. $\times 100$. F, *Xestoleberis* sp. P146939 RV ext. $\times 100$. G, *Neonesidea* sp. P146940 LV ext. $\times 120$. H, *Xestoleberis* sp. P146941 LV ext. $\times 115$. I, *Macro-mackenzia porcelanica* P146942 RV ext. $\times 70$.



Neocytherideis mediata Swanson, 1969

Figured specimen. Fig. 8J (P146972).

Remarks. These specimens are distinctly, but faintly reticulate, with fine punctation within the reticulations (see Fig. 8J). Swanson's illustrations do not show this but specimens of his species fall within the range of variation of this material (Ayress, pers. comm. 1997). Australian *Copypus* specimens, though rare in fossil faunas, are smooth-shelled (McKenzie 1974; McKenzie et al. 1990).

Measurements. P146972—L=0.68, H=0.23, W=0.11.

Material studied. 4 specimens, one a broken juvenile.

Occurrence and age. PL3003. Late Palaeocene.

authors is also visible. They claim the pattern, rather than the nature of the spines is the determining characteristic, since the specimens from Castle Cove and Browns Creek are tuberculate rather than spinose. The younger specimens from Bells Headland (McKenzie, Reymont & Reymont 1991) are sharply spinose.

Measurements. P146960—L=1.37, H=0.61; P146961—L=1.38, H=0.62; P146962—L=0.96, H=0.50; P146963—L=1.02, H=0.48, W=0.42; P146964—L=0.98, H=0.44.

Hypodigm range. L=0.86–1.38, H=0.44–0.62.

Material studied. 249 specimens, mostly broken or fragmentary, but including adults, juveniles and carapaces.

Occurrence and age. PL3003; PL3001; and W. J. Parr Collection slides 15006 and 15008. Late Palaeocene.

Idiocythere Triebel, 1958

Type species. *Idiocythere lutetiana* Triebel, 1958.

?Idiocythere nunkeri

McKenzie, Reymont & Reymont, 1993

Figured specimen. Fig. 7G (P146965).

Remarks. This fragmentary specimen, with its coarsely-punctate surface, its clearly-developed sub-central tubercle and its spinose anterior margin, is similar to *Idiocythere nunkeri* McKenzie et al. (1993: pl. VI, figs 16, 18). However, its small size and fragmentary condition make the assignment tentative.

Measurements. No measurements were possible.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Family TRACHYLEBERIDIDAE

Sylvester-Bradley, 1948

Subfamily TRACHYLEBERIDINAE

Sylvester-Bradley, 1948

Trachyleberis Brady, 1898

Type species. *Trachyleberis scabrocuneata* Brady, 1880.

Trachyleberis careyi

McKenzie, Reymont & Reymont, 1991

Trachyleberis careyi McKenzie, Reymont & Reymont 1991: 169–170, pl. 7, figs 11, 12.

Trachyleberis cf. *careyi* McKenzie, Reymont & Reymont 1993: 105, pl. 6, fig. 8.

Figured specimens. Figs 7A–F, H, J (P146960–P146964, P146966).

Remarks. This species forms the largest single component in the assemblage. The valves are larger and more elongate (especially the males) than those described by McKenzie, Reymont & Reymont (1991, 1993), and the anterior tooth is two-lobed rather than stepped. However, the pattern and polyfurcate nature of the spines, together with the thickened, spinose anterior margins with depressions behind them, establish these specimens as *T. careyi*. At higher magnification, the faint reticulation referred to by these

Dumontina Deroo, 1966

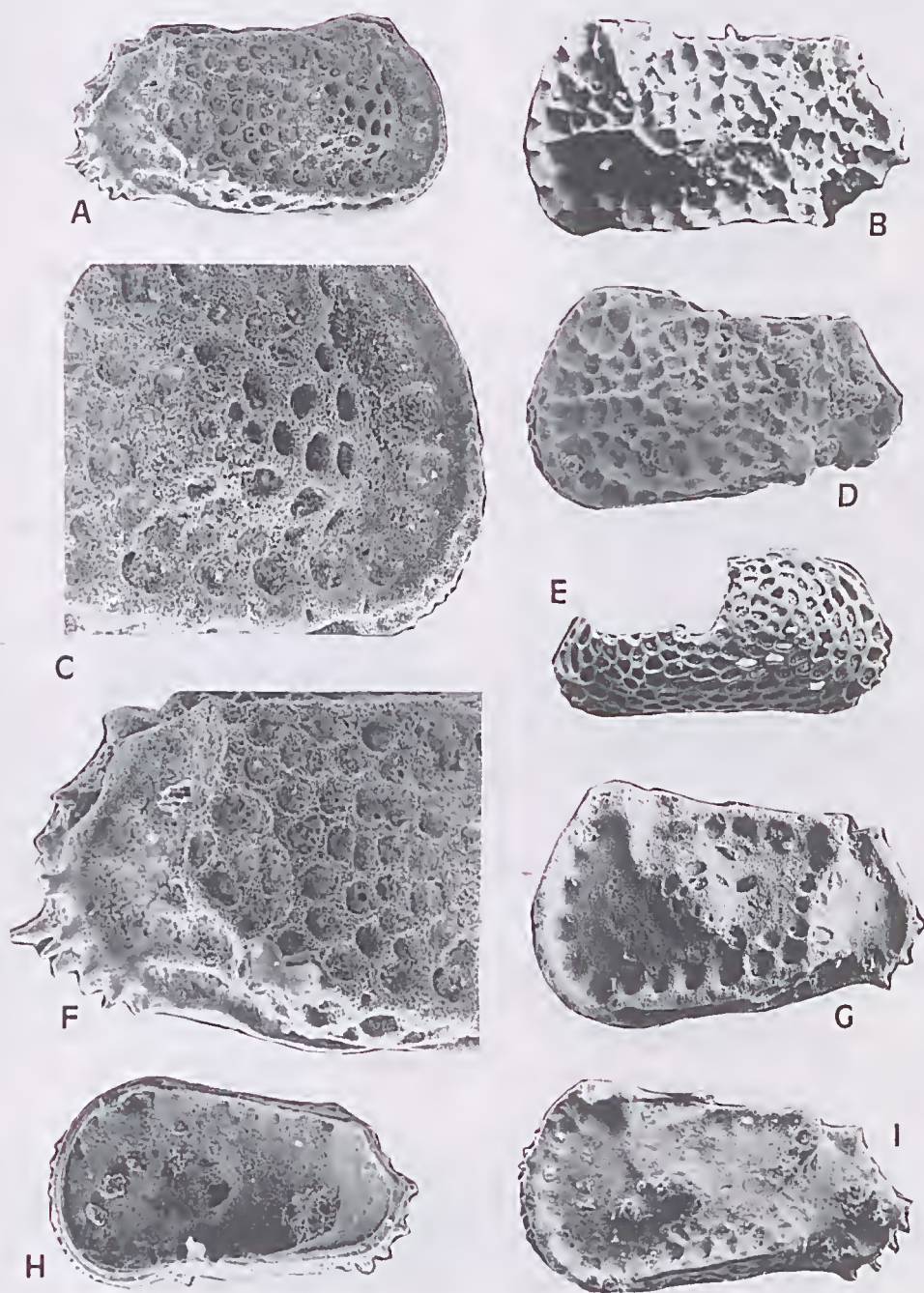
Type species. *Dumontina puncturata* (Bosquet, 1854).

?Dumontina sp. cf. *?D. eratis* Neil, 1994

Figured specimens. Fig. 8A; Fig. 10A (P146967); Figs 9A, B (P146973).

Remarks. These specimens have the general shape, the fine reticulation and the sulcus behind the

Fig. 5. A, *Margocythere* sp. P146943 RV ext. $\times 55$. B, *?Oerthliella* sp. P146944 LV ext. $\times 70$. C, *Margocythere* sp. P146943 RV anterior detail $\times 130$. D, *?Oerthliella* sp. P146945 LV ext. $\times 95$. E, '*Cythereis*' sp. P146946 LV ext. (broken specimen) $\times 70$. F, *Margocythere* sp. P146146943 RV posterior detail $\times 130$. G, *Bradleya semiarata anteropytta* P146947 J, LV ext. $\times 110$. H, *Bradleya semiarata anteropytta* P146948 RV int. $\times 70$. I, *Bradleya semiarata anteropytta* P146949 LV ext. $\times 85$.



anterior margin which characterise ?*D. cratis* Neil, 1994. The broken valve, with a subcentral hole, suggests that the tubercle may have been more strongly developed than in ?*D. cratis*. However, internal details, apart from the hinge structure with the curved anterior socket (Fig. 9B), cannot be determined. The limited material means the assignment to *Dumontina* must remain tentative.

Measurements. P146967—L=0.78, H=0.40; P146973—L=0.72, H=0.40.

Material studied. 2 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Oertliella Pokorný, 1964

Type species. *Oertliella reticulata* Pokorný, 1964.

?*Oertliella* sp.

Figured specimens. Figs 5B, D (P146944, P146945).

Remarks. The allocation of these specimens to *Oertliella* is tentative, because they are not well-preserved, and internal features are impossible to determine. They display a reticulation similar to that of both *Oertliella semivera* (Hornibrook, 1952), and *Spinobradleya echinata* McKenzie et al., 1993, but without the tubercles or spines, except along the dorsum. Small eyespots are present on both specimens. Valve shape is reminiscent of *Agrenocythere antiquata* as figured by Benson & Peypouquet (1983: pl. 1, fig. 7), with spines projecting above the slightly concave dorsal margin (not reproduced clearly in my figures), but the deep-sea genus is ruled out by the presence of eyespots.

Measurements. P146944—L=0.76, H=0.40, W=0.22; P1469945—L=0.61, H=0.32, W=0.14.

Material studied. 2 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Cythereis Jones, 1849

Type species. *Cythereis ciliata* (Reuss, 1846).

'*Cythereis*' sp.

Figured specimen. Fig. 5E (P146946).

Remarks. This single, broken specimen is very similar in reticulation pattern and style to that figured by McKenzie et al. (1993: pl. 6, fig. 9), although a little smaller in size. Since both occurrences are limited to a single specimen, however, the definite allocation to *Cythereis* remains impossible. As McKenzie et al. note 'This could well be a new genus and species.'

Measurements. P146946—L=0.76, H=0.36.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Family HEMICYTHERIDAE Puri, 1953

Subfamily HEMICYTHERINAE Puri, 1953

Margocythere

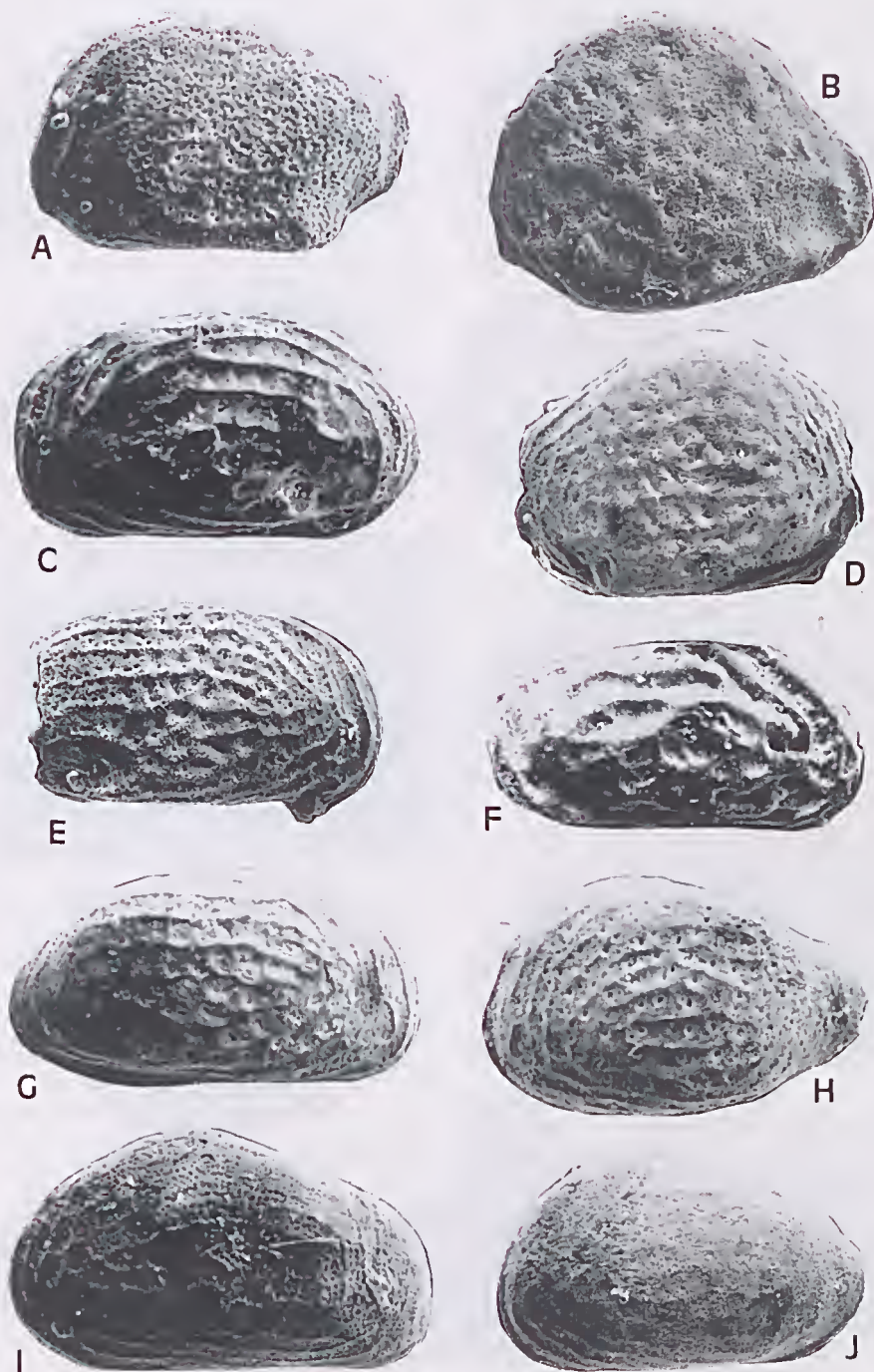
McKenzie, Reymont & Reymont, 1991

Margocythere sp.

Figured specimen. Figs 5A, C, F (P146943).

Remarks. This well-preserved carapace would warrant the erection of a new species if accompanied by additional specimens. However, a description of its main features will assist in that process should new material be found. *Margocythere* sp. is assigned to this genus because of its large size (length about 0.98 mm), its broad margin on the anterior, ventral and posterior of the valves, its ventral ridge and its ruggedly reticulate surface. It differs from the type species, *Margocythere aspreta*, in its very distinctive medio-anterior reticulate swelling (Fig. 5C) and its loculate ventral ridge and anterior marginal area. It differs strongly from *Margocythere latticina* (McKenzie, Reymont & Reymont, 1993) in lacking the criss-cross reticulation pattern of that species.

Fig. 6. A, *Microcytherura* sp. P146950 LV ext. $\times 150$. B, *Kangarina* sp. P146951 LV ext. (broken specimen) $\times 140$. C, *Loxocythere* sp. cf. *L. ouyensis* P146952 LV ext. $\times 120$. D, *Loxocythere malzi* P146953 RV ext. $\times 130$. E, *Loxocythere* sp. aff. *L. hornibrooki* P146954 RV ext. (broken specimen) $\times 120$. F, ?*Callistocythere* sp. P146955 RV ext. $\times 100$. G, *Loxocythere* sp. aff. *L. hornibrooki* P146956 RV ext. $\times 110$. H, *Eucythere* sp. 1 P146957 LV ext. $\times 175$. I, *Rotundracythere rotunda* P146958 LV ext. $\times 175$. J, ?*Nunana* sp. P146959 LV ext. $\times 140$.



The internal features are not known, as preservation with some adherent matrix makes separation of the valves impracticable. The absence of a marked sub-central tubercle with a castrum, as in the thaerocytherid Bradleyinae, corroborates McKenzie et al.'s placement in the Hemicytheridae.

Measurements. P146943—L=0.98, H=0.52, W=0.56.

Material studied. 1 carapace.

Occurrence and age. PL3003. Late Palaeocene.

Family THAEROCYTHERIDAE Hazel, 1967

Subfamily BRADLEYINAE Benson, 1972

Bradleya Hornibrook, 1952

Type species. *Cythere arata* Brady, 1880.

Bradleya semiarata anteropytta McKenzie, Reymont & Reymont, 1993

Bradleya semiarata anteropytta McKenzie, Reymont & Reymont 1993: 112–113, pl. 7, figs 9–11.

Figured specimens. Figs 5G, H, I (P146947, P146948, P146949).

Remarks. Only two adult specimens, both broken, were found. The figured specimens are juveniles (A1 and A2). They show the concave posterodorsal lateral profile, and the shallow reticules of the subspecies. They differ in the greater prominence of the subcentral tubercle, and the presence of some pits on it. The eye tubercle is also less prominent than in the holotype of the subspecies. However, these differences are judged to be intraspecific.

Measurements. P146949—(A1) L=0.77, H=0.35, W=0.16; P146947—(A2) L=0.54, H=0.30, W=0.13; P146948—(A1) L=0.74, H=0.39, W=0.16.

Material studied. 11 specimens, some fragmentary—2 adults, 9 juveniles.

Occurrence and age. PL3003. Late Palaeocene. Hornibrook's nominate subspecies is Altonian–Early Mioene; this subspecies ranges from Late Palaeocene to Late Eocene.

Family CYTHERURIDAE G. W. Mueller, 1894

Subfamily CYTHERURINAE G. W. Mueller, 1894

Hemiparacytheridea Herrig, 1963

Type species. *Hemiparacytheridea occulta* Herrig, 1963.

Hemiparacytheridea sp.

Figured specimen. Fig. 7I (P146967).

Remarks. This single specimen has the characteristic extended cauda, and bitubercular alar structure of the emended diagnosis for *Hemiparacytheridea* of Ayress et al. (1995).

Measurements. P146967—L=0.36, H=0.16.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Eucytherura Mueller, 1894

Type species. *Cythere complexa* Brady, 1867.

Eucytherura sp. 1

Figured specimen. Fig. 8F (P146968).

Remarks. This finely-ribbed specimen is unlike any of those figured by McKenzie et al. (1993) or Whatley & Downing (1983), being free of projections, spines and blades. It does have a general resemblance to *E. indianensis* Ayress et al. (1995), though lacking the aggradational outgrowths on the muri of the reticulation. It is interesting to note that *Eucytherura* is usually rare in any assemblage of which it is a component.

Measurements. P146968—L=0.30, H=0.20.

Material studied. 1 specimen.

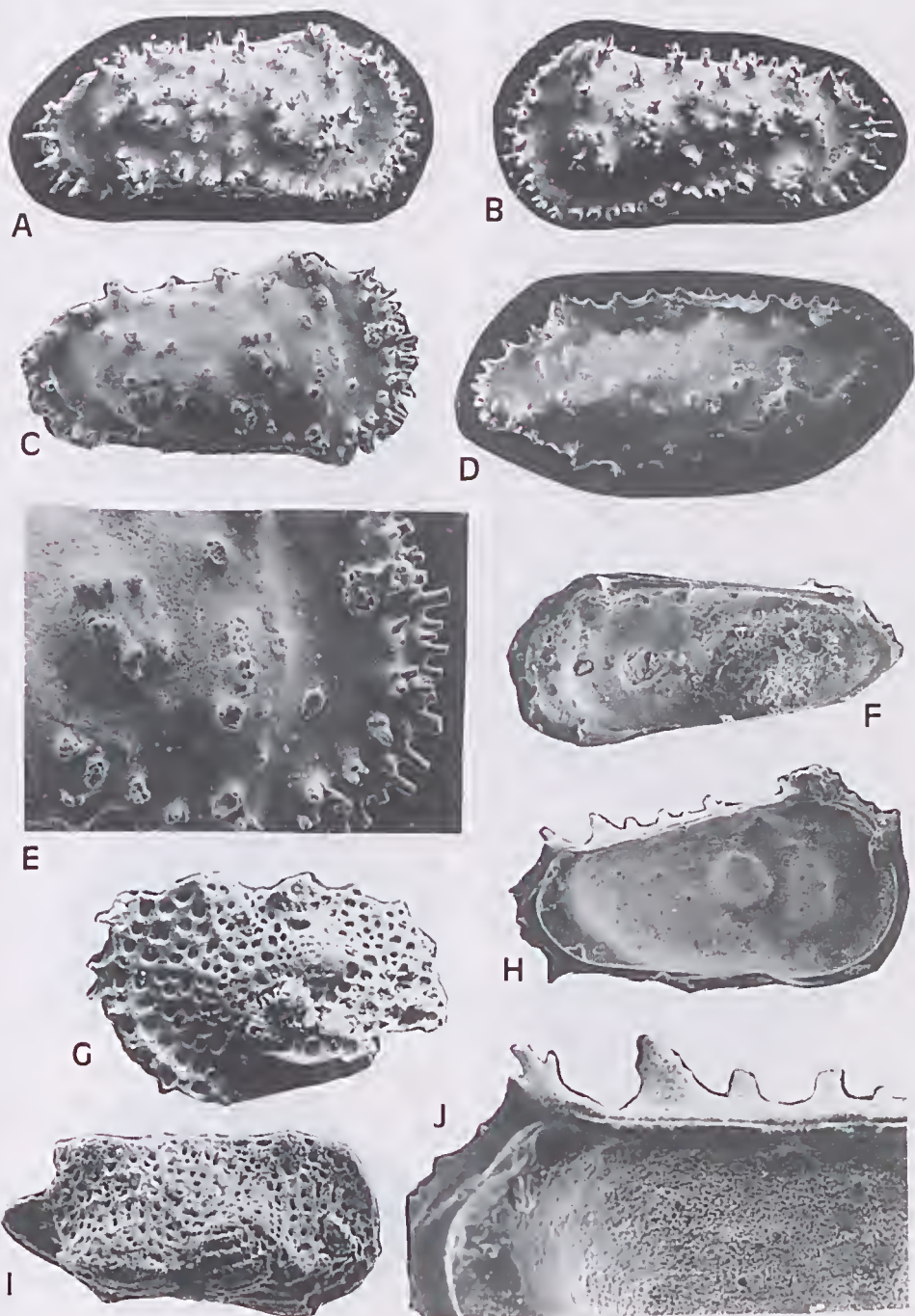
Occurrence and age. PL3003. Late Palaeocene.

Subfamily CYTHEROPTERINAE Hanai, 1957

Pelecocythere Athersuch, 1979

Type species. *Pelecocythere sylvestrbradleyi* Athersuch, 1979.

Fig. 7. All figures are of *Trachyleberis careyi* except G and I. A, P146960 RV ext. $\times 40$. B, P146961 LV ext. $\times 40$. C, P146962 J, RV ext. $\times 65$. D, P146963 C (oblique) $\times 65$. E, P1469962 RV anterior detail $\times 140$. F, P146964 J, RV int. $\times 65$. G, *Eucytherura* sp. indet. 1 P146965 LV ext. (broken specimen) $\times 110$. H, P146966 J, LV int. $\times 65$. I, *Eucytherura* sp. cf. *E.* sp. 1 Whatley & Downing P146967 RV ext. $\times 160$. J, P146966 J, LV int. posterodorsal detail $\times 180$.



***Pelecocythere parageios* sp. nov.**

Etymology. Greek—*parageios* pertaining to shallow water; a reference to the first known shallow-water species of this hitherto deep-water genus.

Types. Holotype P146905; Paratypes P146906–146909.

Figured specimens. Figs 1A, D (P146905); Figs 1B, C (P146906); Figs 1E, G (P146907); Fig. 1F (P146908); Figs 3C, E (P146909).

Type locality. PL3003.

Diagnosis. A *Pelecocythere* species with two angularities on the dorsal margin, and an alar rim not reaching either anterior or posterior margins.

Description. [These characters are described from all the specimens, whole or fragmented, which can be confidently assigned to the species and so constitute the hypodigm.] Carapace large, alate, broadly elliptical in lateral view with greatest height slightly forward of mid-length, length greatest below mid-height. Dorsal margin of carapace narrow, except for a broad ridge in anterior. Dorsal margin of LV broadly rounded with two slight angularities, one anterior to mid-length and one just forward of posterior margin. Dorsal margin of RV with straight dorsum between angularities. Hinge line of LV below highest point of dorsum arch. LV over RV overlap, leaving sector-shaped projection of LV. Anterior broadly rounded; posterior less so, with angularity close to ventral margin. External surface of valves smooth with normal pores evenly distributed over entire lateral surfaces. Venter of each valve flat, marked by one thick ridge and two thinner ones sub-parallel to alar rim; punctate ridges and interareas, with normal pores as on lateral surfaces. Flat venters of RV and LV angled slightly towards the dorsal margin, giving an incurved base. Alar flange is relatively narrow, with 12 or more large, shallow punctae marking junction with lateral surface of valve. Edge of flange a narrow rounded ridge. No eye spots visible externally or interiorly.

Hinge antimerodont, as in type species, with five teeth anteriorly, and six posteriorly in RV and corresponding sockets in LV. Medial element with rounded crenulations in RV, locellate in LV.

Muscle scars of characteristic ecytherid pattern—four adductors, aligned vertically with slight

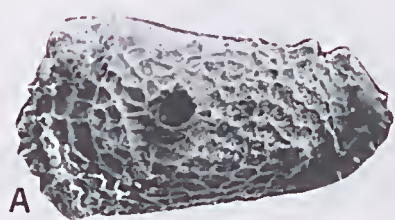
posterior tilt; dorsal sear small and rounded, sub-dorsal sear more elongate and slightly arcuate (concave down), sub-ventral sear elongate and ellipsoidal, ventral sear sub-rounded; frontal sears present but not determinable.

Interior of valve—inner lamella broad anteriorly, with narrow vestibule and numerous branched radial pore canals. Inner lamella very narrow dorsally and posteriorly.

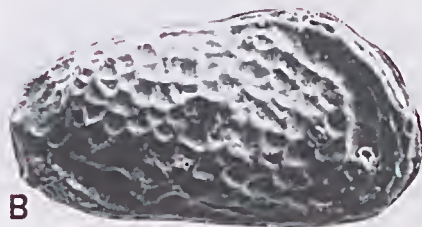
Affinities. *P. parageios* differs from the type species, *P. sylvesterbradleyi* in its angular dorsal margin, its shorter, narrower and unornamented alar flange and its undivided adductor sears. Unlike *P. purii* Neale, 1988, it lacks a marked dorsal ridge, an acutely angled anterior and a caudal process. Its terminal hinge elements are not as strongly developed as in *P. purii*. *P. foramena* Whatley & Coles, 1987 differs from *P. parageios* in its more elliptical shape, its strongly curved ventral margin, its slit-like foramena along the alar margin and its short caudal process. *Pelecocythere* sp. Whatley & Coles, 1987 is probably conspecific with *P. purii*. *Pelecocythere* sp. 1 Whatley & Ayress, 1988 is rather similar to *P. foramena* and so differs from *P. parageios* for similar reasons. *P. trinidadensis* (van den Bold, 1960) ranging from the Middle Eocene to the Middle Miocene, is similar to *P. parageios*, but differs from it in the concavity of the posterodorsal margin, the breadth of the inner lamella posteriorly and the few, simple, straight radial pore canals. *Cytheropteron* (*Cytheropteron*) *carinoalatum* Bate 1972 from the Upper Cretaceous of the Carnarvon Basin in Western Australia may well be an ancestral form of *Pelecocythere*, since it shows most of the characteristic morphology of the genus, except for the smooth surface of the valves and the alar process. Its occurrence in relatively shallow basin deposits may support this evolutionary hypothesis. *Paraphysocythere riedeli* Swain, 1973 from the Maastrichtian of DSDP Site 48.2 bears a superficial resemblance in lateral view to *Pelecocythere* species, but has a marked peripheral ridge on all valve margins, and a different hinge structure.

Remarks. *Pelecocythere parageios* sp. nov. is the oldest recorded species of this genus. From its size and comparative abundance it forms a

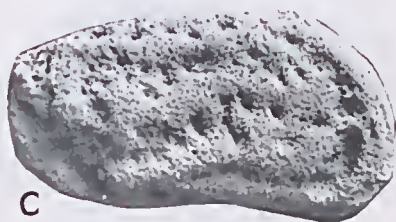
Fig. 8. A, ?*Dumontina* sp. cf. *D. cratis* P146967 LV ext. $\times 70$. B, *Munseyella* sp. cf. *M. adaluma* P146922 RV ext. $\times 140$. C, *Munseyella* sp. cf. *M. warringa* P146923 RV ext. $\times 130$. D, *Leptocytherid* gen. and sp. indet. P146924 RV ext. $\times 140$. E, ?*Munseyella* sp. P146925 LV ext. (deformed?) $\times 140$. F, *Eucytherura* sp. indet. 1 P146968 LV ext. $\times 150$. G, *Eucythere* sp. 2 P146969 LV ext. $\times 170$. H, *Eucythere* sp. 2 P146970 RV ext. $\times 110$. I, *Loxocythere malzi* P146971 RV int. $\times 125$. J, *Neocytherideis mediana* P146972 LV ext. $\times 95$.



A



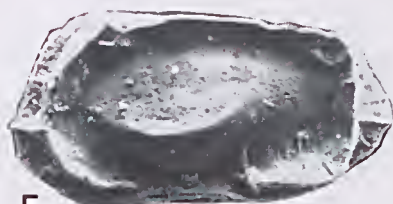
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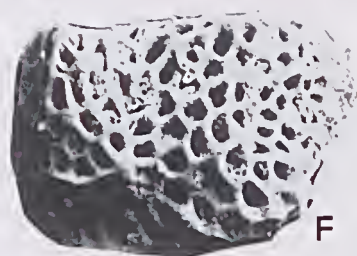
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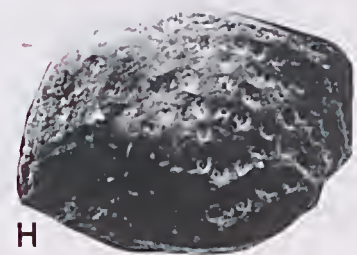
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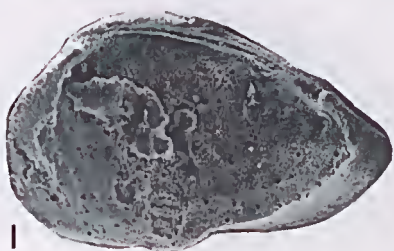
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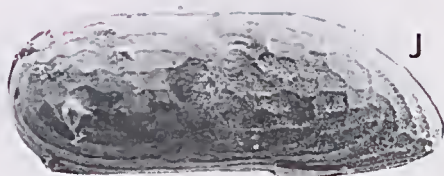
G



H



I



J

characteristic component of the Pebble Point fauna. The occurrence of *Pelecocythere parageios* in this Late Palaeocene shallow-water fauna is of particular significance because it is the earliest recorded occurrence of this genus, which is characteristic of deep-water ostracode assemblages ranging from the Early Eocene to the Recent (Benson & Peypouquet 1983; Coles, Ayress & Whatley 1988; Whatley & Ayress 1988; Whatley & Coles 1991). It is also significant because it is the only recorded shallow-water occurrence of *Pelecocythere*. Previous records of *Pelecocythere* spp. range in depth from 950 m (Correge 1993) to 4796 m (Neale 1988). Even the Early Eocene occurrence is recorded from >1000 m (Coles & Whatley 1989).

This change in depth habitat by the genus *Pelecocythere* over time reinforces the suggestion (Whatley & Dingle 1989) that some taxa presently inhabiting deep water (>1000 m) originated on the shelves of continental margins. These authors suggest that the deep-water genus *Poseidonamicus* Benson, 1972 probably arose in Australasia from shallow-water Late Cretaceous stock, though *Poseidonamicus* has not been found in the shallow water Tertiary record of either New Zealand or Australia. In fact they admit surprise that a sighted *Poseidonamicus* was encountered in waters off the southern African Atlantic coast rather than in Australasian waters. Unlike the ancestor of *Poseidonamicus*, *Pelecocythere*, and the possible ancestor of *Pelecocythere*, *Cytheropteron* (*Cytheropteron*) *carinoalatum* Bate, 1972, are both blind species. The occurrence of these earliest forms in the Australasian region, albeit in the widely separated Carnarvon Basin of Western Australia and the Otway Basin of southern Victoria, is consistent with the evolutionary hypothesis (Whatley et al. 1983) that SW Pacific shallow-water genera have given rise to cosmopolitan deep-water species of these genera right through the Tertiary to the Recent. Speculation by Coles, Ayress & Whatley (1990) that *Pelecocythere* may have originated in the North Atlantic was qualified by their proviso that additional sampling might produce new evidence. This is now the case.

The subsidence of the region between Australia and New Zealand allowed species to adapt to increasingly deeper habitats (Whatley 1983), though the rate of that subsidence has been claimed to be rapid by Ayress (1994). Unpublished work by Millson (1987) has illustrated material of Palaeocene age from DSDP cores in the Tasman which has affinities with *Pelecocythere*. In the light of these occurrences, further work is necessary if the evolutionary process suggested here is to be confirmed. The location of the Late Palaeocene *P. parageios* in the Otway Basin, which occupies one of a series of extensional basins which developed as an E-W trending trough in response to Cretaceous (Cenomanian) rifting between Antarctica and Australia (Veevers & Eittrheim 1988), is generally consistent with this hypothesis. However, the present-day Otway Shelf (<100 km wide) remains a high energy environment, with continuous particle abrasion to 70 m, constant movement of calcareous sands to 130 m and occasional reworking of outer shelf and upper slope sediments (Boreen et al. 1993), so that the migration of the inner shelf fauna to deeper waters, perhaps through turbidity currents, seems feasible and would have been necessary for *P. parageios* to follow the evolutionary strategy referred to above. The patterns and rates of subsidence in the Otway Shelf area may not be related to those occurring in the Tasman Sea.

Measurements. Holotype, P146905—L=1.14, H=0.74, W=0.60; Paratypes, P146906—L=?, H=0.65; P146907—L=?, H=?, W=0.62; P146908 (Juvenile)—L=0.51, H=0.25.

Hypodigm specimens come within this range, with adults having length/height ratio of approximately 1.5:1, and juveniles having a length/height ratio of 2:1.

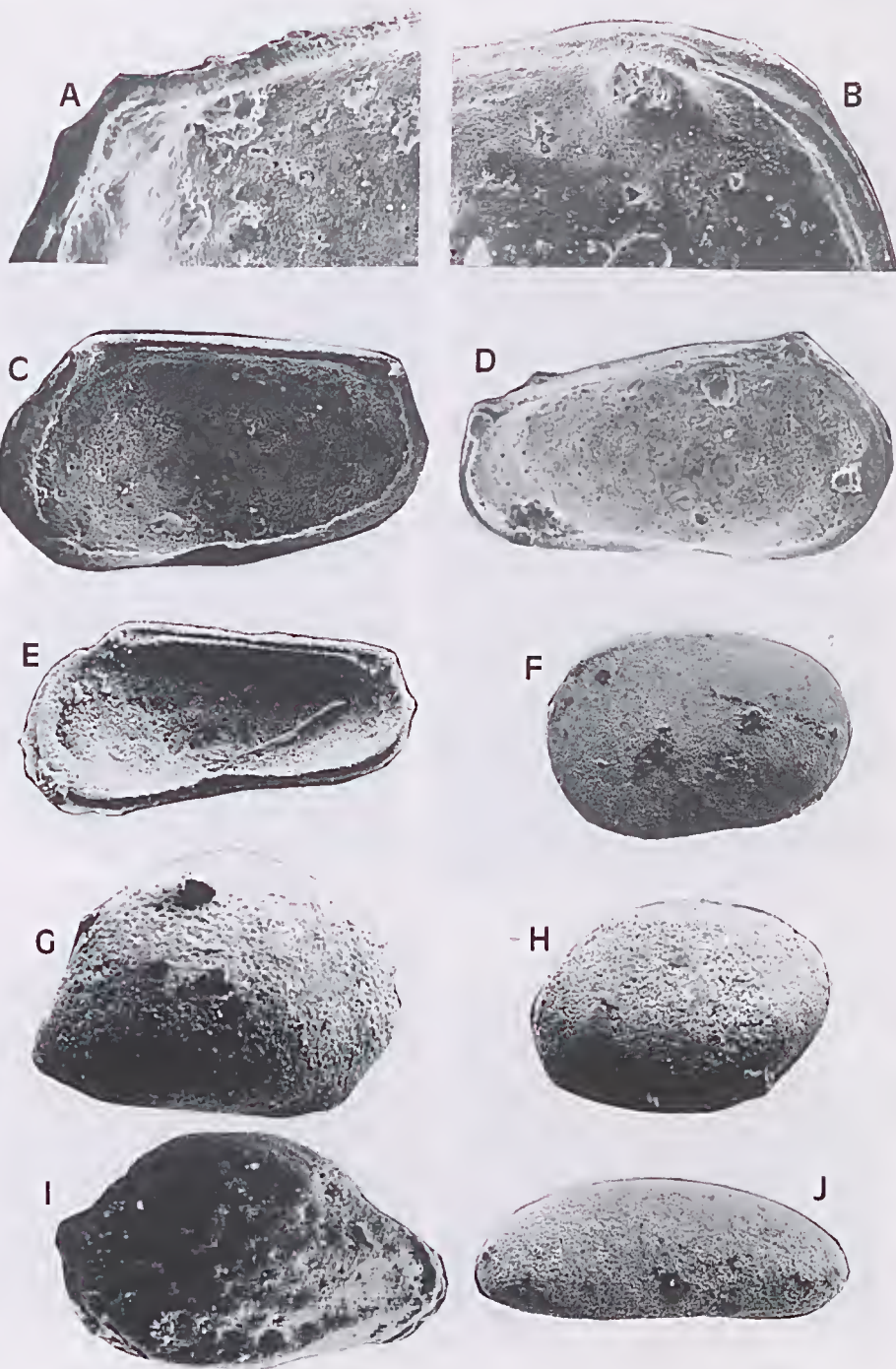
Material studied. 75 specimens, including single valves, carapaces, and identifiable fragments.

Age and occurrence. PL3001; PL3003. Late Palaeocene.

Oculocytheropteron Bate, 1972

Type species. *Oculocytheropteron praenuntatum* Bate 1972.

Fig. 9. A, ?*Dumontina* sp. cf. *D. cratis* P146973 LV int. posterior hinge element detail $\times 200$. B, ?*Dumontina* sp. cf. *D. cratis* P146973 LV int. anterior hinge element detail $\times 200$. C, *Munseyella* sp. cf. *M. bungoona* P146919 RV int. $\times 150$. D, *Munseyella kleithria* sp. nov. P146913 LV int. $\times 140$. E, *Munseyella kleithria* sp. nov. P146914 RV int. $\times 110$. F, *Cytherella pinnata* P146974 LV ext. $\times 50$. G, *Neonesidea* sp. P146975 RV ext. $\times 110$. H, Gen. et sp. indet. P146976 LV ext. (specimen lost) $\times 140$. I, *Kangarina* sp. P146977 RV ext. $\times 140$. J, ?*Argilloecia* sp. P146978 C (LV) $\times 80$.



?*Oculocytheropteron australopunctatarum*

McKenzie, Reymont & Reymont, 1991

Oculocytheropteron australopunctatarum McKenzie, Reymont & Reymont 1991: 154, pl. 6, fig. 1; pl. 7, figs 1, 2.

Oculocytheropteron australopunctatarum Majoran 1995: fig. 3P.

Figured specimens. Figs 3A, J (P146927, P146934).

Remarks. The surface punctuation, shape and alar configuration of these specimens in both male and female valves is clearly conspecific with the Late Eocene species from the Blanche Point Formation of South Australia figured by McKenzie et al. (1991). The specimen figured by Majoran (1995) does not show the surface punctuation very clearly. The diagnostic significance of the eyespot in the genus *Oculocytheropteron* is taxonomically debatable, and hence the assignment of all species in this fauna to this genus must be regarded as open to question.

Measurements. P146927—L=0.55, H=0.33, W=0.20; P146934—L=0.42, H=0.27, W=0.25.

Material studied. 2 specimens, one slightly crushed.

Occurrence and age. PL3003. Late Palaeocene.

?*Oculocytheropteron* sp. 1

Figured specimen. Fig. 3F (P146930).

Remarks. A finely reticulate species, which differs from *O. australopunctatarum* in having a finely ridged ornamentation, a longer and more pointed cauda and a convex venter. An unequivocal placement in *Oculocytheropteron* has not been made because an eye spot cannot be determined (see note above), though the nature of the alar process and the posterodorsal to subcentral ridge are said to be consistent *Oculocytheropteron* characteristics (Ayress, pers. comm. 1997).

Measurements. P146930—L=?, H=0.25; P146933—L=0.50, H=0.22, W=0.31 (Carapace).

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

?*Oculocytheropteron* sp. 2

Figured specimens. Figs 3B, D (P146928, P146929).

Remarks. A more coarsely punctate species than *O. australopunctatarum* with some longitudinal ribs posteriorly. Surface ornamentation of ribs and punctuation and general shape are reminiscent of a Middle Miocene species occurring at Muddy Creek, near Hamilton (Neil 1992), but the poorer preservation of these specimens prevents close comparison. ?*O.* sp. 2 has an eye, though it is not as strongly developed as in Bate's type species *O. praenuntatum* (in fact few described *Oculocytheropteron* species have prominent eye tubercles). ?*O.* sp. 2 bears little resemblance to the other Australian oculocytheropteronids (Whatley & Downing 1983; Yassini & Jones 1995), but is rather similar to *Cytheropteron* (C.) *obtusulum* Hornibrook, 1952, which is described as ranging from Runangan (Late Eocene) to Recent in New Zealand.

Measurements. P146928—L=0.44, H=0.28; W=0.12; P146929—L=0.46, H=0.31, W=0.12.

Material studied. 38 specimens.

Occurrence and age. PL3003; PL3001. Late Palaeocene.

***Aversovalva* Hornibrook, 1952**

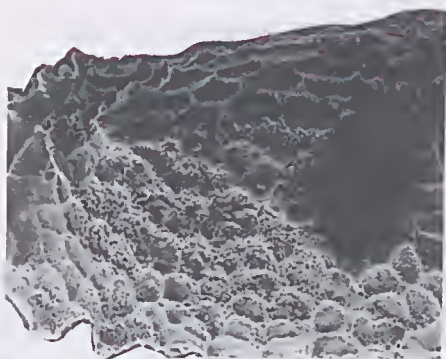
Type species. *Aversovalva aurea* (Hornibrook, 1952).

***Aversovalva* sp.**

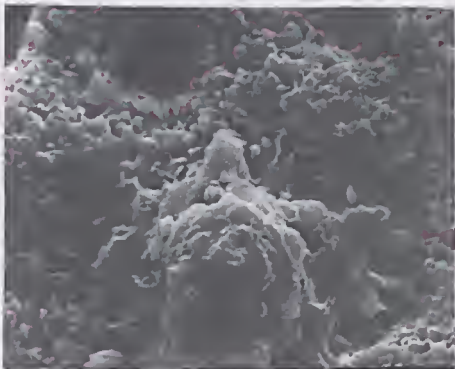
Figured specimens. Figs 3H, I (P146933); Fig. 10E (P146932).

Remarks. The small size, smoothly curved dorsum and straight hinge line of these specimens are diagnostic of the genus, though LV/RV overlap was not established. The alar process is relatively small and rounded for this genus and distinguishes it from the Late Oligocene *A. cooperi* McKenzie, Reymont & Reymont 1991. The surface is finely, but not uniformly, punctate (Fig. 10E). Majoran (1995) has figured a specimen, *Aversovalva* sp. 2, from the Late Eocene of the Tortachilla Limestone and the Blanche Point Formation in South Australia, which may be conspecific with *Aversovalva* sp.

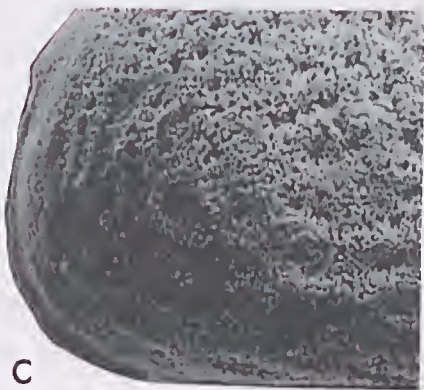
Fig. 10. A, ?*Dumontina* sp. cf. *D. cratis* P146967 detail of surface ornament $\times 130$. B, *Munseyella* sp. cf. *M. adaluma* P146915 detail of surface structure $\times 1200$. C, *Eucythere* sp. 2 P146969 detail of surface ornament $\times 350$. D, *Microcytherura* sp. P146979 detail of surface ornament $\times 450$. E, *Aversovalva* sp. P146932 detail of surface $\times 350$. F, *Munseyella warringa* P146918 detail of antero-dorsal margin $\times 425$.



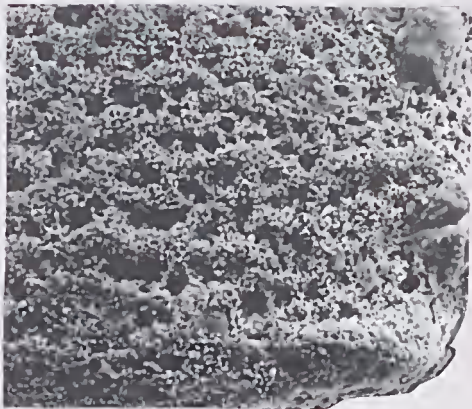
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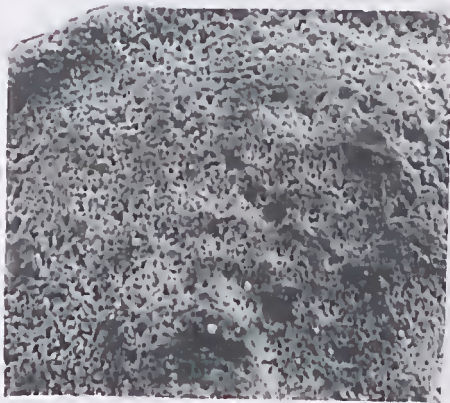
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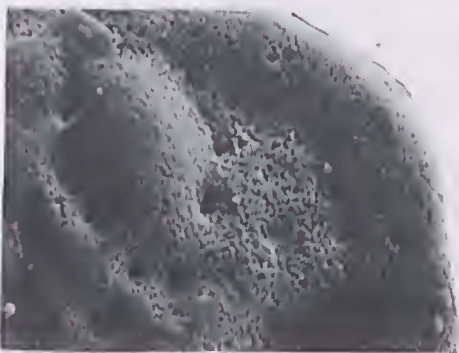
C



D



E



F

Measurements. P146932—L=0.40, H=0.24, W=0.18.

Material studied. 8 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Kangarina Coryell & Fields, 1937

Kangarina sp.

Figured specimens. Fig. 6B; Fig. 9I (P146951, P146977).

Remarks. This species is characterised by a coarsely punctate surface free of ribs. It is unlike any other species of *Kangarina* figured from south-east Australia. Poor preservation prevents further assignment.

Measurements. P146951—L=?, H=0.30, W=0.12; P146977—L=0.44, H=0.30, W=0.13.

Material studied. 2 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Subfamily CYTHERURINAE Mueller, 1894

Hemicytherura Elofson, 1941

Hemicytherura sp.

Figured specimen. Fig. 3G (P146931).

Remarks. This single specimen is poorly-preserved, but the shape is characteristic of *Hemicytherura*. There is some surface punctation but no clear connection with the hemicytherurids figured by McKenzie et al. (1991, 1993). A suggestion that this specimen may be linked with *Amplicytherura dinglei* McKenzie et al., 1993, and consequently with *Schizocythere* (McKenzie, pers. comm. 1997) is not borne out by the more strongly-arched dorsum of this specimen, and the absence of the schizodont hinge.

Measurements. P146931—L=0.32, H=0.21.

Material studied. 1 specimen.

Occurrence and age. PL3003. Late Palaeocene.

Family XESTOLEBERIDIDAE Sars, 1928

Xestoleberis Sars, 1866

Type species. *Xestoleberis aurantia* (Baird, 1838).

?Xestoleberis sp. 1

Figured specimen. Fig. 4H (P146941).

Remarks. These specimens differ from the xestoleberids figured by McKenzie et al. (1991, 1993). *Xestoleberis* sp. 1 has a more evenly rounded anterior than either *X. basiplana* or *Xestoleberis* sp., and is more elongate than *X. noccia*. Preservation and matrix infilling make it difficult to give a more detailed description, or assign to *Xestoleberis* other than tentatively.

Measurements. P146941—L=0.42, H=0.21.

Material studied. 17 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Xestoleberis sp. 2

Figured specimen. Fig. 4F (P146939).

Remarks. These specimens are somewhat similar in shape to *Foveoleberis minutissima* (Chapman, 1926), but are not pitted, nor do they have the caudal process diagnostic of both *Foveoleberis* and *Uroleberis*. The slightly convex venter is unusual for this genus, and the highly-arched dorsum is unlike any other Australian fossil xestoleberids.

Measurements. P146939—L=0.50, H=0.31, W=0.13.

Material studied. 3 specimens.

Occurrence and age. PL3001, PL3003. Late Palaeocene.

Family NUNANIDAE

McKenzie, Reymont & Reymont, 1993

Nunana McKenzie, Reymont & Reymont, 1993

Type species. *Nunana australiae* McKenzie, Reymont & Reymont, 1993.

?Nunana sp.

Figured specimen. Pl. 6, fig. J (P146959).

Remarks. The small size and poor preservation of these specimens, some infilled with adherent matrix, makes diagnostic features difficult to determine, but they are very tentatively assigned to *Nunana*, although the specimens are generally larger than those referred to by McKenzie et al. (1993). The ventral region is inflated and striate as in *N. australiae* and the anterior has a flange, but the presence of a subdued reticulation differentiates it from this smooth-shelled species. Where the hinge line can be examined, specimens are adont, but this may be a juvenile condition.

Measurements. P146959—L=0.41, H=0.22.

Material studied. 23 specimens.

Occurrence and age. PL3003, PL3001. Late Palaeocene.

Family MACROCYPRIDIDAE Mueller, 1912

Macromackenzia Maddocks, 1990

Type species. *Macrocypris siliquosa* Brady, 1887.

Macromackenzia porcelanica (Whatley & Downing, 1983)

Macrocypris porcelanica Whatley & Downing 1983: 383, pl. 1, figs 11–13.

Macromackenzia porcelanica (Whatley & Downing).—Maddocks 1990: 54.

Macromackenzia porcelanica (Whatley & Downing).—McKenzie, Reymont & Reymont 1991: 144, pl. 2, figs 5, 6.

Macromackenzia sp. aff. *porcelanica* (Whatley & Downing).—Yassini and Jones 1995: 311, figs 114, 116, 118, 120, 122.

Figured specimen. Fig. 41 (P146942).

Remarks. External and internal features, including shape, muscle scars and duplicature, establish these specimens as *M. porcelanica*, thus extending its range from Late Palaeocene through Middle Miocene probably to Recent (Yassini & Jones 1995). In shape, these Palaeocene specimens are closer to Recent forms illustrated by Yassini & Jones (1995) with a less acuminate posterior than the Miocene specimens figured by Whatley & Downing (1983) and McKenzie, Reymont & Reymont (1991).

Measurements. P146942—L=0.82, H=0.35.

Material studied. 38 specimens, some broken, and including carapaces. No juveniles.

Occurrence and age. 36 specimens from PL3003; 2 from PL3001. Late Palaeocene.

Family PONTOCYPRIDIDAE MUELLER, 1894

Argilloecia Sars, 1866

Type species. *Argilloecia cylindrica* Sars 1866.

?Argilloecia spp.

Figured specimen. Fig. 9J (P146978).

Remarks. Owing to the poor preservation and matrix-infilled condition of these specimens, only

a tentative assignment to the genus is made on the basis of shape and size alone. At least two species are represented, one elongate with an evenly arched dorsum (Fig. 9J); the other smaller, with a more acutely arched dorsum.

Measurements. P146978—L=0.58, H=0.20.

Material studied. 9 specimens, including 2 carapaces.

Occurrence and age. PL3003. Late Palaeocene.

Maddocksella McKenzie, 1982

Type species. *Bythocypris tumefacta* Chapman 1914.

Maddocksella sp.

Remarks. Poorly preserved fragmentary or broken specimens preclude assignment beyond the generic level. However, the robust, relatively inflated valves, some showing the distinctive rosette muscle-scar pattern, are characteristic of *Maddocksella* which McKenzie et al. (1993) have recorded from the nearby Late Eocene Brown's Creek Clays.

Measurements. Specimens too fragmentary to measure.

Material studied. 10 specimens.

Occurrence and age. 7 from PL3003; 3 from PL3001. Late Palaeocene.

Family PARACYPRIDIDAE Sars, 1923

Subfamily PARACYPRIDINAE Sars, 1923 (*partim*)

Tasmanocypris McKenzie, 1979

Type species. *Tasmanocypris dartmalli* McKenzie 1979.

Tasmanocypris sp.

Figured specimens. Figs 4D, E, I (P146937, P146938, P146942).

Remarks. The limited number of specimens precludes the creation of a new species. However, the broad inner lamella and the muscle scars are diagnostic for the genus. These specimens differ from *T. eurylamella* McKenzie et al. (1991) in having a more evenly arched dorsum, and a less broad inner lamella ventrally. There is no anterodorsal convexity as in *T. dietmaykeyseri* (Hartmann, 1979). In lateral view, *T.* sp. is closest to *T. setigera* (Brady, 1880).

Measurements. P146937—L=0.78, H=0.35, W=0.32; P146938—L=0.76, H=0.36; P146942—W=0.82, H=0.35.

Material studied. 3 specimens.

Occurrence and age. PL3003. Late Palaeocene.

Family UNKNOWN

Genus and species indeterminate

Figured specimen. Fig. 9H.

Remarks. This fragile specimen was broken subsequent to being photographed, and has not been allocated a P number. It was of small size (H=0.20), smooth-shelled and of distinctive ovoid shape, which may indicate a juvenile cytherellid.

DISCUSSION

The composition of this assemblage presents a number of problems in palaeoecological and palaeobathymetric interpretation from a uniformitarian point-of-view.

The occurrence of a new species of *Pelecocythere* in the Palaeocene provides a substantial argument for the shallow-water origin of this otherwise cosmopolitan deep-sea index genus, since many of the characteristics of this assemblage point to a shallow-water or at least inner-shelf environment. However, as has been pointed out above, *Pelecocythere parageois* is a blind species. An ancestral sighted species from a shallow-water environment with blind descendant species in the deep sea is a persuasive combination of evidence. A blind ancestral species with blind descendants in the deep sea is less convincing, though blind species in shallow-water environments are common enough.

Dingle and Lord (1990—quoted in Szczecura 1995) point out that deep-water ostracodes may live in shallow waters if these are cold enough, relatively low saline and less oxygenated. Such cold, low saline, minimum oxygen waters may result from an upwelling or an influx from off the shelf, but there is insufficient palaeoecological evidence from this assemblage to warrant drawing that conclusion.

Whatley et al. (1983) refer to the SW Pacific area (and by extension, Bass Strait) as experiencing the invasion of the deep-water from the shallow by ostracode genera as essentially a one-way traffic. They illustrate this by reference to the genera *Poseidonamicus* and *Bradleya*, both of which have

sighted, shallow-water ancestral species. It seems unlikely that *P. parageois* ran counter to this pattern, especially as it is the oldest species of the genus yet described. Inferences about palaeobathymetry on the basis of a uniformitarian interpretation of Recent ostracode genera will always be tentative. For instance, Whatley (1983) has indicated that 'a distinct species group of the normally phylal genus *Xestoleberis* occurs at both bathyal and abyssal depths'.

On balance, it seems that indicators of a shallow, marine shelf environment for this assemblage—the abundance of pectocytherids (McKenzie 1979), leptocytherids and some cytherurids including *Hemicytherura*; the macrofauna (Darragh 1994); the foraminiferida (McGowran 1965) and Baker's original (1950) investigation of the facies of the Pebble Point Formation—provide substantial evidence for proposing the beginning of the evolutionary development of the genus *Pelecocythere* from *P. parageois*.

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